

## METHOD OF MANUFACTURE OF TAPES OF CARBON STEEL, IN PARTICULAR OF STEEL FOR PACKAGING, AND TAPES THUS PRODUCED

The invention relates to the iron and steel industry. More precisely, it relates to the manufacture of steel tapes intended to be transformed into Packaging having low thickness, such as boxes for drinks and food

The traditional process of manufacture of steel tapes intended to be then transformed into packaging of low thickness, in particular for drinks and foodstuffs, comprises the following stages: - continuous casting slabs of carbon steel; - hot rolling of these slabs on a wide strip mill with a temperature of end of rolling higher than the  $A_r3$  temperature of the nuance considered; - cold rolling of the tape hot thus obtained, this cold rolling being able to be carried out in a single stage, or two stages being able to be separated by a thermal processing, according to the desired final thickness for the tape; - reheated tape cold thus obtained, by annealing bases or reheated continuous.

In practice, the thicknesses of the final tapes after cold rolling and annealing are about 0.09 to 0.40 mm. These tapes are then cut out in sheets and/or blanks, which are pressed to form required packing.

This die of manufacture is long and expensive in energy, owing to the fact that it requires the use of separate installations. In particular, the rolling of slabs on the wide strip mill is expensive, in particular because these heated slabs owe beforehand to be with high temperature. In addition, the wide strip mill is a tool requiring a high investment.

**\*\*\*time-out\*\***

this disadvantage can be circumvented by replacing the unit cast continuous for some reheating-train with tape by an installation of casting direct of strip metal of thickness lower with 10 mm. This solution has been proposed in the document JP 09-001207, which teaches to run directly starting from metal molten, on an installation of run between two cylinders contrarotating cool internally, of tape of which the composition corresponds with a nuance traditional of steel for packing ( $C\% \leq 0,15$ ;  $Mn\% \leq 0,6$ ;  $P\% \leq 0,025$ ;  $S\% \leq 0,025$ ;  $Al\% \leq 0,12\%$ ;  $N\% \leq 0,01$ ;  $O\text{ total}\% \leq 0,007\%$ , all these contents being expressed of percentages by weight). < # S > the tape thus run undergoes then a scouring, the first cold rolling, an annealing of recrystallization and the second rolling cold. The total reduction ratio undergone by the tape during cold rolling lies between

85 and 95% if one wants to obtain satisfactory results on the rate of the horns of stamping, the anisotropic coefficient  $R$  and the planar anisotropy  $\Delta r$ . Casting between cylinders can be followed by a slight hot rolling with a reduction ratio from 20 to 50%, even more. The manufacture of the hot tape which must then undergo cold rolling and the associated processing is thus faster and more economic. However, the need for then carrying out a cold rolling in two stages separated by an annealing moderates these advantages.

The goal of the invention is to propose a process more economic than the processes known for obtaining tapes of steel rolled cold usable for the manufacture of packing, in particular for food packing such as boîtesboisson.

To this end, the invention has as an aim a manufacturing process of tapes of carbon steel, in particular of steel for packing, according to which: - one runs in the form of a metal strip from 0,7 to 10 mm thickness, directly starting from molten metal, a steel having a composition adapted to a use as steel for packing; - one carries out an operation of hot rolling in line of the aforementioned tape, finishing in the austenitic field of the aforesaid steel; - one carries out a forced cooling of the aforementioned tape at 80 to 400 C/s finishing in the ferritic field of the aforesaid steel; - one carries out a cold rolling of the aforementioned tape at a reduction ratio of 85% at least; - and an annealing of the aforementioned tape is carried out.

The invention also has as an aim a tape of carbon steel, in particular of steel for packing, characterized in that it likely of be is obtained by the preceding process.

As one will have included/understood, 1' invention rests on the use of a process of run between cylinders followed by at least a stage of hot rolling on line and of a particular cooling of the tape. One thus obtains a hot tape which tolerates to undergo then only one stage of cold rolling (except the traditional final passage to the skin-pass) to see itself conferring the properties which return it adapted to the manufacture of steels for packing.

The invention will be included/understood better with the reading of the description which follows.

The process according to the invention starts with casting in the form of metal strips from 0,7 to 10 mm thickness (preferentially from 1 to 4 mm) of a semi-finished product to low or ultra-low percentage of carbon of a steel which can be used for 1' packing of traditional

composition. This composition, for the principal elements present, answers the principal criteria (the percentages are expressed in percentages by weight):  $0\% \leq C \leq 0,15\%$ ;  $0\% \leq Mn \leq 0,6\%$ ;  $0\% \leq P \leq 0,025\%$ ;  $0\% \leq S \leq 0,05\%$ ;  $0\% \leq Al \leq 0,12\%$ ;  $0\% \leq N \leq 0,04\%$ . This steel contains moreover usual impurities resulting from the development, and possibly from the alloy elements in small quantity which will not unfavourably affect the properties of the products at the time of their working or their use as steels for packing (he is thus known, in certain steels for packing, to introduce few thousandth % of boron), the remainder being iron. The alloy elements, in general absent, can, possibly, be present in contents being able to go up to 1%; These elements are in particular Si, Cr, Ni, Mo, Cu. For lawful reasons, certain elements of alloys are excluded when steel is intended for 1' packing; these elements are for example lead, cadmium and arsenic.

Continuous casting metal strips directly starting from molten metal is a technique which has been tested for several years for the casting of steel to carbon, stainless steels and other ferrous alloys. The technique most usually used in run metal ferrous alloy strips, and which is arriving at the industrial stage, is the technique known as of run between cylinders, according to which one introduces molten metal between two brought closer cylinders with horizontal axes, put in rotation in direction opposite and cooled internally. The space of casting is sealed laterally by refractory plates applied against the plane side faces of the cylinders. Solidified metal skins are formed on each cylinder, and meet on the level of the collar (the zone where the difference between cylindrical side surfaces of the cylinders is weakest and corresponds appreciably to the thickness wished for the tape) to form a solidified tape. This technique is particularly recommended for the invention because it gives access to the thicknesses of tape of a few mm, and one will refer to it in the continuation of description. But one can use other processes of direct casting of metal strips, such as casting between two tapes in run which makes it possible to run products a little thicker than casting between cylinders. However, one of the advantages of run between cylinders is the possibility of obtaining, if necessary, of the profiles thickness of the tape in direction through extrmement flat, thanks to the excellent control of convex cylinders which allow the modes of practical application of this process most advanced (see, for example, document EP 0 736 350).

To its output of the cylinders, the tape crosses, preferably, a zone such as an inerted enclosure by a gas blowing, where it is subjected to an environment not oxidizing (a neutral atmosphere of nitrogen or argon, even an atmosphere comprising a certain proportion of hydrogen

to make it reducing), in order to avoid or to limit the calamine formation to its surface. At output of this zone of inertage one can also place a device of decarbonizing of the tape by projection of shot or CO, solid on his surface or by brushing, in order to eliminate the calamine which could have been formed in spite of the precautions taken. One can also choose to let create calamine in a natural way without seeking with inerter the atmosphere surrounding the tape, then to eliminate this calamine by a device such as one has just described it. The presence of calamine on the tape, in general, is not wished, because of the risks of incrustation of this calamine in the surface of the tape during later rolling. Such incrustations lead to a poor surface quality of the products. Moreover, calamine increases the efforts of rolling to be applied, and degrades the surface quality of the cylinders of the rolling mill.

As much as possible immediately after the output of the tape of the installation of inertage or decarbonizing, if there is one of them, has place an operation of hot rolling of the tape, followed by a strong cooling. The goal of this processing is to obtain a tape having: - a thickness lower than 3 mm (typically 0,9 mm) which, in connection with the reduction ratios which will be used during the cold rolling which will follow, will allow to obtain final tapes having the desired thickness; - a metallurgical structure which, always in connection with the processing undergone later on by the tape, makes it possible to obtain on the tape the mechanical properties necessary for the future use of metal, for example like steel for packing; - a profile through flatter than those obtained with the conventional processes.

To arrive to this result, two alternatives of diagrams of manufacture are proposed.

According to the first alternative, one carries out a single stage of hot rolling of the tape, finishing at a temperature higher than the  $A_{r3}$  temperature of the cast steel, in other words in the austenitic field. This hot rolling is carried out with a minimal reduction ratio of 20%, and preferentially this rate is higher than 50%. This hot rolling has as functions: - to close again porosities which can be present at the heart of the tape after its casting; - to break the microstructure of solidification; - and to improve the surface quality of the tape by crushing the reliefs which can be present at the surface of the tape, in particular when one used at the time of run cylinders having a relatively strong roughness which can be advantageous for the optimization of the thermal transfers between the cylinders and the solidified skins.

This single stage of hot rolling can be carried out by means of the passage of the tape in only one rolling mill stand. It can also be carried out in a more progressive way while making pass the tape in two rolling mill stands or more. The first cage can, for example, to apply with the tape an only sufficient reduction ratio to close again porosities, and the second cage then ensures the major part of the reduction thickness making it possible to fulfil the two other functions of hot rolling.

Essence is that the total reduction ratio caused by this or these passages in the successive cages and the temperature of the tape after its passage in the last cage is in the ranges of prescribed values.

According to the second of these alternatives, hot rolling is carried out in two stages, separated by a reheating, and possibly by a decarbonizing. The first of these stages is carried out either in the austenitic field, or in the ferritic field of the run tape, with a reduction ratio of 20 à 70%. It has functions identical to those of the single stage of hot rolling of the first alternative, and can also be carried out by the passage of the tape in one or more successive rolling mill stands.

Preferentially, this first stage of rolling takes place in the ferritic field when one wants to obtain a final thickness of the weak tape, but of less efforts are necessary to deform the tape in a regular way over all its width that when the tape is in the austenitic field. When one carries out this first stage of hot rolling by distributing it on several cages, it is however possible to begin this first stage in the austenitic field, for example by a relatively light rolling which would mainly aim at closing again porosities, and to finish it in the ferritic field where one would carry out the remainder of the reduction thickness. After this first stage of hot rolling, one lets the tape cool until in the ferritic field if it is not there already (with the need using a slight forced cooling), then one applies a thermal processing of reheating to him which brings back it in the austenitic field, therefore above the temperature  $A_{r3}$ . One thus causes an additional phase shift in the tape, which has as a consequence a refinement even more thorough of the grains of the metallurgical structure. Then one carries out the second stage of hot rolling, in the austenitic field, with a reduction ratio from 10 to 30%. This second hot rolling has as a function essential to correct the geometrical defects (bad flatness, sabres...) that the first hot rolling could cause. Intermediate reheating can be carried out by means of an inductor that crosses the tape.

For a tape thickness 0,75 mm and width 850 mm travelling at a speed of 200 m/mn, a power of 1,04 MW are necessary if a rise in temperature of 100 C is required. Consequently, if one uses an inductor with solenoid in longitudinal flow functioning with 500 kHz, of which the output is usually about 45%, a length of inductor of 2 m approximately (of which 1,5 m of useful zone) is adapted to this use. If the tape has a lower thickness, one can use the technology of induction heating under transverse flow, described in particular in the document High flow induction for the fast heating of semi-product steel in line with rolling (Proceedings of the XIII International Congress on Electricity Applications, Birmingham, June 1996). But in a general way, other more conventional technologies, such as a muffle furnace under controlled atmosphere, or of the radiant tubes, can be used to ensure this reheating.

The two alternatives which come from the described have thus as a common point to end in a rolling carried out on the tape in austenitic phase, which is thus completed afterwards Ar3. temperature In both cases, the process according to the invention continues with a cooling of the tape which comprises a stage of cooling forced at 80 to 400 C/s, preferentially 100 to 300 C/s. This cooling is completed in the ferritic field of the cast steel, and in general brings the tape to a temperature close to its temperature of winding. The purpose of it is to avoid a too significant growth of the size of the grains before the winding and during the stay of the tape in the form of reel. This temperature of winding is typically lower at 750 C For the nuances calmed with aluminium, the temperature of winding can be selected around 550 C or 600 C or 700 C in order to more or less support the aluminium nitride precipitation.

It is significant for the reliability of obtaining the properties sought for the tape that this forced cooling is carried out in a homogeneous way over all the bandwidth. One can quantify at 10 C the desirable maximum amplitude of the differences in temperature of a point to another of the bandwidth at a given moment. This homogeneity is more difficult to guarantee if the speed of cooling is high, which justifies the recommendation a maximum speed of 400 C/s. Conversely, a minimal speed of 80 C/s ensures that cooling will have the desired metallurgical effectiveness.

Such speeds of cooling can be obtained, in particular, by water projection by means of jets with high pressure, or by projection of a water-air or similar mixture (atomization). This forced cooling can begin just after austenitic rolling from the tape, but it is advised to begin it only after having let the tape cool at low speed (approximately 10 C/s, which is accessible by a simple exposure to the

free air) and pass in the ferritic field, therefore below Ar<sub>3</sub>. In this way, one benefits fully from refinement of the grain related to the phase shift austenite-ferrite, whereas a fast cooling which would begin in the austenitic field gnerait the homogeneity of the microstructure appreciably. It should be noted however that accelerated cooling should not begin, preferably, at a temperature lower than Ar<sub>3</sub>-10 C.

In a general way, the use of a fast cooling before winding makes it possible to avoid the presence of coarse grains in skin of the tape, which are particularly undesirable on steels for packing. Indeed, those must have, after cold rolling, a very great homogeneity of their final characteristics.

The wound tape then unreeled undergoes then a cold rolling ata reduction ratio from at least 85%, preferably more than 90%. This cold rolling can tre perfectly carried out by simple reduction, i.e. in only one stage, and not imperatively in two stages with intermediate annealing as it was the case in document JP 09-001207 already quoted (cold rolling with double reduction). One obtains aptitudes for stamping comparable with those obtained by the known processes, and one has access to thicknesses of tape lower than the 0,09 mm of the processes known without having to resort to a cold rolling with double reduction. If one does not wish to obtain tapes finer than usually, one can obtain the traditional thicknesses with less reduction ratios during cold rolling, which is more economic. Il is, of course, possible to carry out a cold rolling of the tape in double reduction if one wishes to obtain a thickness even lower or higher mechanical characteristics.

As an indication, one can present the table 1 which gives examples final thicknesses of the tape according to its initial thickness after cast and of the rates of rolling applied at the time of the stages of hot rolling (in one or two stages according to the selected alternative) and of cold rolling.

Thickness of the tape runs (mm).	3	3	2	1.5
Rate of the mining with heat (%).	65	70	60	50
Thickness of the hot tape (mm).	1.05	0.9	0.8	0.75
Rate of cold rolling (%) final	85-92	85-92	85-92	85-92
Thickness of the tape (mm)	0.158-0.084	0.135-0.072	0.12-0.064	0.113-0.060

Table 1: Thickness of the tapes obtained according to the various parameters of cast and rolling

After cold rolling, the tape undergoes annealing (bases or continuous) usual intended to confer its mechanical properties to it. This annealing can be followed, as usual, by a scouring, one revtement and/or a passage to the skin-pass.

**\*\*time-out\*\***

the velocity de emission of tape of rolling mill hot be about 250 m/mn or less, these speed be compatible with a setting on a line single of it rolling mill (therefore of line of casting as a whole son ensemble) and of one or more of operation of rolling cold, of annealing and of processing cold of steel for packing, of which the flow of metal be compatible with that of rolling mill hot. One can quote like examples of such operations, in addition to scouring and the skin-pass which can follow annealing, a lacquering, a varnishing, a polymer deposit, for example by coextrusion, a vacuum deposit by plasma or electronic bombardment, revtement metal by electrodeposition. If the operation of cold rolling takes place on line with the operation of cast and hot rolling, that implies the suppression of the stage of tape spooling.

If the invention finds an applicability privileged in the manufacture of steel tapes intended for tre pressed to form packing for drinks or food out of preserve, it goes without saying it can apply to the manufacture of tapes of steel intended for other uses for which similar qualities would be required for the produced tapes.

**Claims**

1) Manufacturing process of tapes of carbon steel, in particular of steel for packing, according to which: - one runs in the form of a metal strip from 0,7 to 10 mm thickness, directly starting from molten metal, a steel having a composition adapted to a use as steel for packing; - one carries out an operation of hot rolling in line of the aforementioned tape, finishing in the austenitic field of the aforesaid steel; - one carries out a forced cooling of the aforementioned tape at 80 to 400 C/s finishing in the ferritic field of the aforesaid steel; - one carries out a cold rolling of the aforementioned tape at a reduction ratio of 85% at least; - and an annealing of the aforementioned tape is carried out.

2) Process according to claim 1, characterized in that the



aforementioned tape is run between two horizontal rolls put in rotation in direction internally cooled opposite.

3) Process according to the claim 1 or 2, characterized in that the aforementioned operation of hot rolling is carried out in a single stage with a reduction ratio from at least 20%.

4) Process according to claim 3, characterized in that the aforementioned operation of hot rolling is carried out in a single stage with a reduction ratio from at least 50%.

**\*\*time-out\*\***

5) Process according to the claim 1 or 2, characterized in that the aforementioned operation of rolling hot be carry out in two stage, in it that the first of these stage be carry out with a ratio de reduction of 20 à 70%, in it that after this first stage, one heat the tape so as to it make pass of field ferritic in the field austenitic of the aforesaid steel, and in it that one carry out then the second stage of rolling with a ratio de reduction of 10 with 30%, this one himself finish in the field austenitic of the aforesaid steel.

6) Process according to claim 5, characterized in that the aforementioned first stage is carried out entirely in the ferritic field of the aforesaid steel.

7) Process according to claim 5, characterized in that the aforementioned first stage is carried out to some extent in the austenitic field and in the ferritic field of the aforesaid steel.

8) Process according to one of claims 1 to 7, characterized in that after his casting, one makes cross to the tape a zone where it is subjected to an environment not oxidizing.

9) Process according to one of claims 1 to 8, characterized in that front and/or during hot rolling one subjects the tape to an operation of decarbonizing.

10) Process according to one of claims 1 to 9, characterized in that the aforementioned forced cooling is carried out at 100 to 300 C/s.

11) Process according to one of claims 1 to 10, characterized in that the aforementioned forced cooling begins when the tape is in the ferritic field of the aforesaid steel.

12) Process according to one of claims 1 to 11, characterized in that the tape is wound at a temperature lower at 750 C between forced cooling and cold rolling.

13) Process according to one of claims 1 to 12, characterized in that the reduction ratio of cold rolling is at least 85%.

14) Process according to one of claims 1 to 13, characterized in that the aforementioned cold rolling is carried out in only one stage.

15) Carbon steel band, in particular of steel for packaging, characterized in that it is likely to be obtained by the process according to one of claims 1 to 14.

16) Carbon steel band according to claim 15, characterized in that steel has as a composition in percentages by weight  $C \leq 0,15\%$ ;  $Mn \leq 0,6\%$ ;  $P \leq 0,025\%$ ;  $S \leq 0,05\%$ ;  $Al \leq 0,12\%$ ;  $N \leq 0,04\%$ , the remainder being iron, impurities resulting from the development, and possibly from the alloy elements not empchant the use of the aforementioned tape to manufacture steels for packing.